SimTek - an edX-based platform for mathematical multi-physics simulation

S. Banzas (1), C. Alonso-Montes (2), J. Jansson (2,*)

(1) Fac. Informatics Universidade da Coruña (SPAIN) (2) BCAM - Basque Center for Applied Mathematics (SPAIN) (*) Computational Technology Laboratory, School of Computer Science and Communication, KTH (SWEDEN)

infsbb00@udc.es,{calonso,jjansson}@bcamath.org

I. State of the art

Massive Open Online Course (MOOC) platforms, e.g. Coursera[1], edX[2] and Udacity[3], are used by a wide variety of higher education institutions, offering online courses worldwide. Computational Mathematics (CM) and in particular Computational Fluid Dynamics (CFD) is widely used in many industrial sectors (e.g. aeronautics, medicine, etc) which requires high skills in mathematics as well as engineering. In this scenario, a MOOC platform plays a great role offering several educational resources adapted to different educational backgrounds, dealing with a diverse student segment (ranging from pure mathematicians towards engineers in various disciplines). The SimTek platform aims to provide a range of educational resources related to CM, and also offers a web interface to the FEniCS[4] framework for multiphysics simulation with the possibility of using remote High-Performance Computing (HPC) resources. The main goal is to reduce the learning step to approach mathematical multi-physics simulation combined with allowing students to formulate their own simulations using FEniCS remotely. We have used experience from teaching CM and CFD courses, mainly at KTH and BCAM, to define aims and specifications for the platform.

II. SimTek: An overview

FEniCS allows a user to build advanced multi-physics simulation programs or “solvers” based on a few lines of high-level mathematical input, in principle the partial differential equation (PDEs) in mathematical notation describing the multi-physics phenomena. However, good programming knowledge (in Python) and good mathematical skills are required, especially for beginners. Furthermore, CFD simulations can require large computational time and resources, not being readily available to students. Finally, the lack of an integrated graphical user interface makes usage of the FEniCS technology difficult by non-experts.

SimTek was defined as an edX-based platform providing a basic web infrastructure to host educational resources related with PDEs, mathematical computing, multi-physics simulations etc, as well as interface to HPC remotely with FEniCS. Several technologies were integrated to tailor to our needs (see Illustration 1): a code editor with syntax highlighting and error reporting, the integration with ParaViewWeb[5] to visualize the solutions, and the integration of FEniCS as a remotely solver engine to be used in combination with HPC resources.

Basic security has also been implemented. The code editor eases the usage of FEniCS by non-expert users, thanks to availability in a web interface with syntax highlighting and error reporting. ParaViewWeb allows the user to interact with the solutions, in the same way as standalone applications. Moreover, there is the possibility to provide access to HPC capabilities through the edX infrastructure for remote execution.

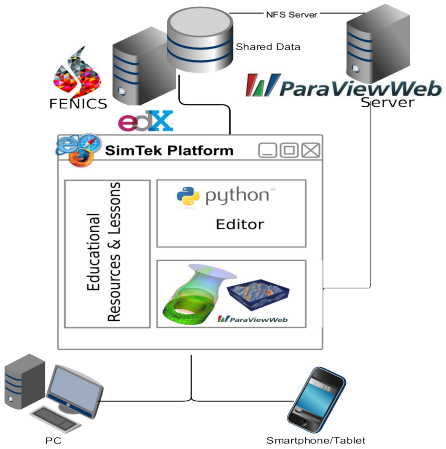

Illustration 1: Diagram of the SimTek system

III. Future developments

SimTek offers an initial platform to distribute and share specific educational material for courses in CM and CFD. It can also serve as a shared resource to access to remote usage of FEniCS on HPC resources. However, the SimTek development showed some issues to be taken into account. The learning curve to set up and to tailor edX to specific needs is high, due to the lack of documentation. In some cases, customized solutions were done to satisfy our requirements. Security, especially regarding Python execution, is still an issue in scenarios with untrusted users.

The SimTek platform will be tested in two courses during Spring 2015, offering student feedback for future development.

Acknowledgments

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References

[1] Coursera official website (2015): https://www.coursera.org/
[2] edX official website (2015): https://www.edx.org/
[3] Udacity official website (2015): https://www.udacity.com/
[4] FEniCS project, official website (2015): http://fenicsproject.org/
[5] ParaViewWeb(2015): http://www.paraview.org/Wiki/ParaViewWeb

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(*) Computational Technology Laboratory, School of Computer Science and Communication, KTH (SWEDEN)
infsbb00@udc.es,{calonso,jjansson}@bcamath.org

Motivation

The SimTek platform aims to provide a range of educational resources related to computational mathematics, and also offers a web interface to the FEniCS framework for multiphysics simulation in mathematical notation with the possibility of using remote High Performance Computing (HPC) resources. The main goal is to reduce the learning step to approach mathematical multi-physics simulation.

SimTek General Schema

Features

Python Editor
Syntax highlingting
Error reporting performed online, before sending to execute

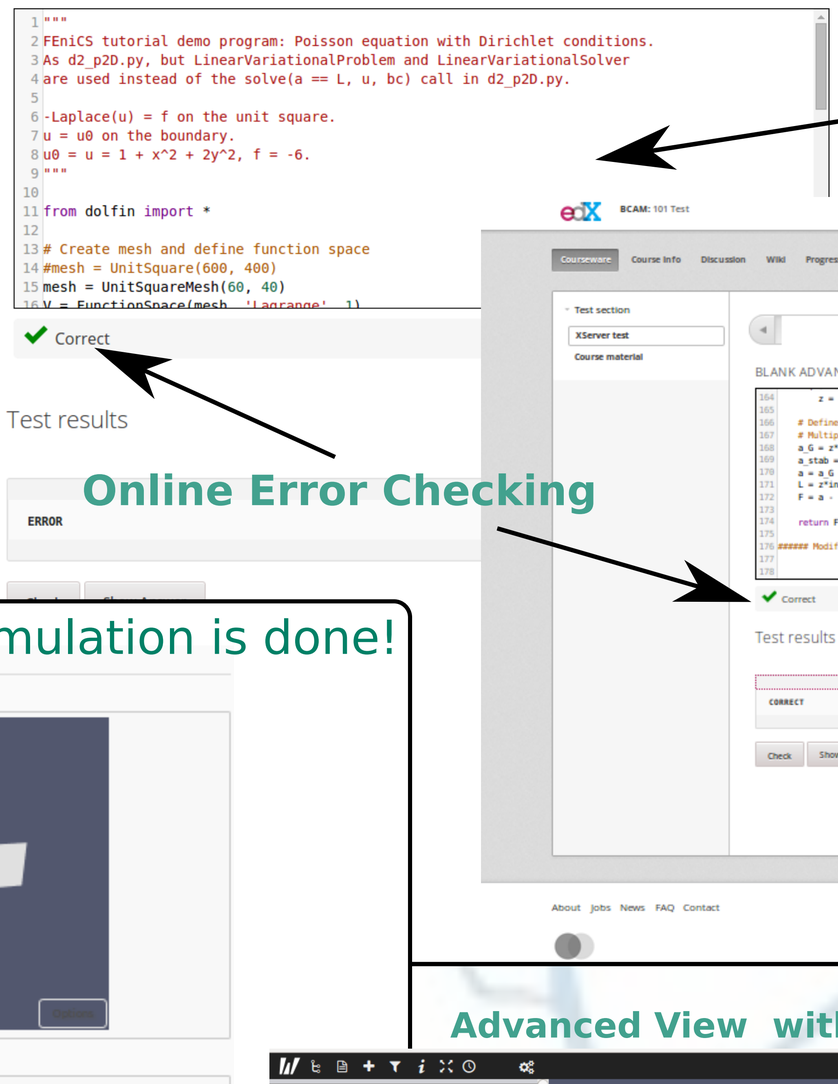
Remote execution with FEniCS
Possibility to use external & remote HPC resources, making these resources available for the large public

Web Visualization of the solution
ParaViewWeb for output visualization
Advanced User Interaction of the final solution

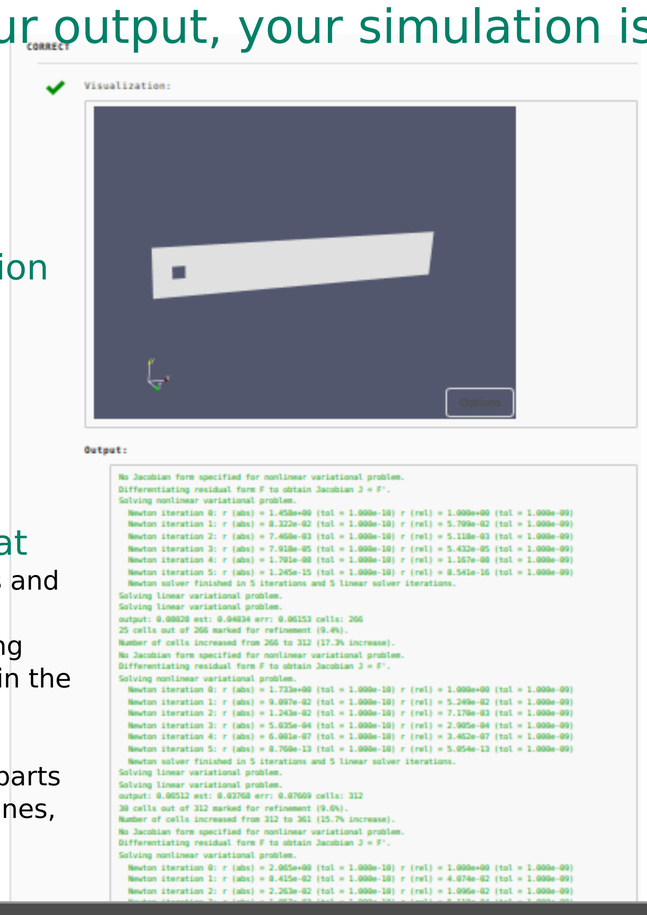
Security
Basic security implemented to access the platform
Security on the execution of external code

* Image from FutUndBeidl in Flickr

1. Specify your equation and program: debug & run



2. See your output, your simulation is done!



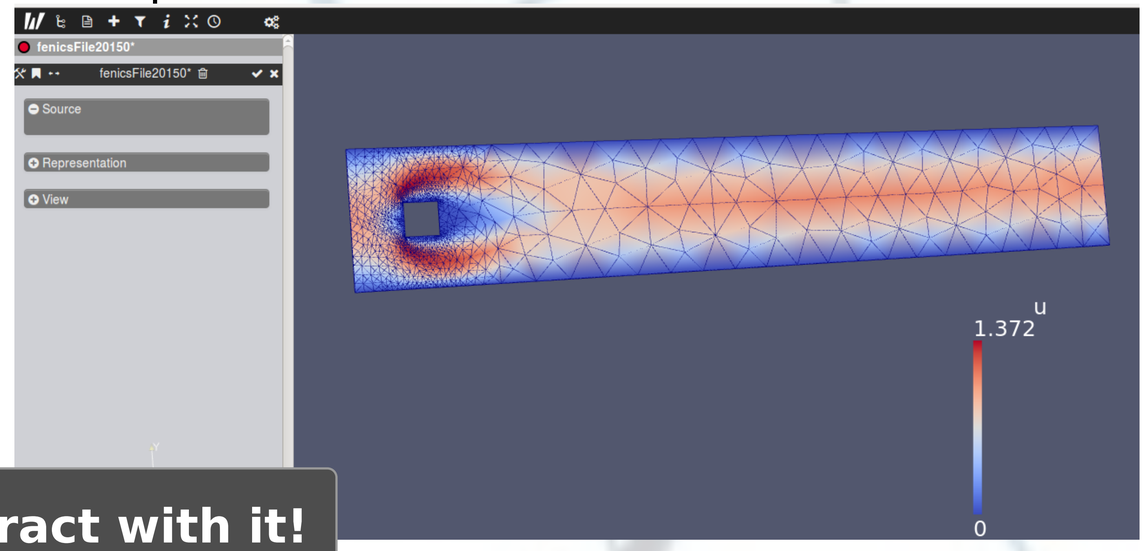
Check your numerical output of your solution

You will always have all the information
of your solution in several formats
Pick up the one that better fits your needs!

Your simulation output is in Paraview format

ParaView is an open-source, multi-platform data analysis and visualization application built on top of VTK.
SimTek has an embedded version of ParaviewWeb offering several functionalities to interact with your solution within the platform:
* Move it in the 3D space
* Change to different perspectives or zoom the solution parts
* Choose among several types of visualizations (streamlines, oriented glyphs, contours/isosurfaces, colormaps, etc)

Advanced View with advanced user interaction



See your solution and interact with it!

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[3] Udacity official website (2015): https://www.udacity.com/
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[5] ParaViewWeb(2015): http://www.paraview.org/Wiki/ParaViewWeb

basque center for applied mathematics
EUSKO JAURLARITZA GOBIERNO VASCO
HEZKUNTZA, HIZKUNTZA POLITIKA ETA KULTURA SAILA
DEPARTAMENTO DE EDUCACIÓN, POLITICA LINGÜÍSTICA Y CULTURA
BFA DFB Bizkaiko Foru Aldundia Diputación Foral de Bizkaia
GOBIERNO DE ESPANA MINISTERIO DE ECONOMIA Y COMPETITIVIDAD
EXCELENCIA SEVERO OCHOA